

# Effect of Slope on Growth of Three Hard Broadleaved Tree Species in Northeast China

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**Abstract** Analysis on tree height and diameter(DBH) growth of the belt-mixed plantations of *Fraxinus mandshurica*, *Phellodendron amurense* and *Juglans mandshurica*(planted in 1986) were conducted by using the methods of variance analysis and multiple comparison. The results show that the position of slope is a significant physical factor to affect height growth and DBH growth. *Fraxinus mandshurica* grew best at middle hill. *Juglans mandshurica* grew best at mid-down slope, and *Phellodendron amurense* grew best at down slope. The analysis of the positive edge effect was also made for belt-mixed plantation of *Juglans mandshurica* and *Larix dahurica*. The result indicated that *Larix dahurica* presented positive edge effect to growth of *Juglans mandshurica* present.

**Key words:** Slope position, *Fraxinus mandshurica*, *Juglans mandshurica*, *Phellodendron amurense*, Plantation forest

## Research Site

The study was carried out in Maoershan Experimental Forest Farm of Northeast Forestry University (45°20' ~ 45°25' N and 127°30'~127°34' E). The average elevation of this area is 300 m. Annual average temperature is 2.7 °C. Annual average precipitation is 720 mm. Frost-free period is 120~140 days. Soil type is typical dark brown forest soil. The vegetation belongs to Changbai Mountain flora. Broad-leaved Korean pine forest as primitive climax community has become typical natural secondary forest due to disturbance and destroy from mankind in recent 100 years. The slope exposure of investigation site is to NE, 880 m in length and 150 m for relative difference of elevation.

## Methods

Study site was set up at clear-cut stand (56 hm<sup>2</sup>) of secondary forest (clear cut in 1984 ). Belt-mixed forest were planted along the slope with 2 years seedling in 1986. The mixed disposition is: broadleaved belt consisted of 6 lines of trees, and conifer belt consisted of three lines. We choose one belt of *Fraxinus mandshurica*, one belt of *Juglans mandshurica*, and one belt of *Phellodendron amurense* respectively. Plots were set up in these three belts from down hillside to top of hill. Fifty trees were selected randomly from each plot to measure their diameter and height, meantime, and one standard tree was selected as analytic tree for measuring annual growth rate. We measured water content of soil

and unit weight of soil in every plot.

The following equations were used in variance analysis<sup>[3]</sup>:

$$D = \sqrt{\frac{\sum_{i=1}^n D_i^2}{n}}$$

where:  $D$ --Average DBH in plot;

$n$ --The total number of measured trees;

$D_i$  — practical measured DBH of  $i$ th tree.

$$F = \frac{S_b^2}{S_w^2}$$

where:  $F$ --Variance;  $S_b^2 = \frac{L_b}{n-1}$ ;  $L_b = \frac{\sum_{i=1}^a T_i^2}{m-c}$ ;

$$S_w^2 = \frac{L_w}{a(m-1)}; \quad L_w = L_T - L_b; \quad L_T = \sum_{i=1}^a \sum_{j=1}^m X_{ij}^2 - C.$$

The following equation was used in multiple comparison

$$LSD = t_{0.05} \sqrt{\frac{2S_e^2}{m}}$$

where:  $LSD$  is Least significant digit

## Results and Analysis

The averages of DBH(cm ) and height (m) for these tree species at various slope positions were listed in Table 1. Middle slope is the best site for growth of diameter and height of *Juglans mandshurica*. The DBH

and height average 7.5 cm and 7.6 m respectively, bigger than that at down slope. Middle slope is also the best site for *Fraxinus mandshurica*. Its DBH and height average 4.7 cm and 4.8 m respectively. Down slope is the best site for *Phellodendron amurense*. DBH and height average 4.7 cm and 4.9 m respectively.

**Table 1. Average DBH (cm) and average height (m) of different tree species at various slope**

Species	Slope position					
	up		middle		down	
	DBH	Height	DBH	Height	DBH	Height
<i>Juglans mandshurica</i>	5.6	6.4	7.5	7.6	7.2	7.2
<i>Fraxinus mandshurica</i>	2.9	3.4	4.7	4.8	3.6	4.7
<i>Phellodendron amurense</i>	2.9	3.2	3.5	4.7	4.7	4.9

Variance analysis demonstrates that there exists significant difference in DBH growth for the three tree species at different slope positions (Table 2 and 3). The height growth of every species is same as DBH growth.  $F$  value of height and DBH of *Phellodendron amurense* is much higher than  $F_{0.05}$ . Slope is more important factor that affects height growth of *Juglans mandshurica* and *Fraxinus mandshurica*.

**Table 2. Variance analysis for diameter (DBH) at different position of slope**

	<i>Phellodendron</i>	<i>Fraxinus</i>	<i>Juglans</i>
interclass deviation sum of square	70.62	79.24	75.72
intraclass deviation sum of square	350.21	210.26	104.98
interclass degree of freedom	2	2	2
intraclass degree of freedom	147	147	147
interclass average variance	35.31	39.62	37.86
intraclass average variance	2.38	1.43	0.71
$F$	14.82	27.70	53.01
$F_{0.05}$	3.06	3.06	3.06
test of significance	**	**	**

**Table 3. Variance analysis of trees' height at different position of slope**

	<i>Fraxinus</i>	<i>Juglans</i>	<i>Phellodendron</i>
interclass deviation sum of square	93.50	78.10	85.43
intraclass deviation sum of square	158.19	93.96	64.96
interclass degree of freedom	2	2	2
intraclass degree of freedom	147	147	147
interclass average variance	46.75	39.05	42.72
intraclass average variance	1.08	0.64	0.44
$F$	43.44	61.09	96.66
$F_{0.05}$	3.06	3.06	3.06
test of significance	**	**	**

Multiple comparison was adopted to analyze the difference of up-, middle-, and down-slope (see Table 4).

**Table 4. Multiple comparison analysis of every factor for diameter growth (DBH)**

Level	Average DBH	$x_i - x_{up}$	$x_i - x_{down}$	LSD (0.05)
<i>Fraxinus mandshurica</i>				
I	$x_{middle}=4.7$	1.8**	1.1**	0.6572
II	$x_{down}=3.6$	0.7*		
III	$x_{up}=2.9$			
<i>Juglans mandshurica</i>				
I	$x_{middle}=7.5$	1.9**	0.3	0.5068
II	$x_{down}=7.2$	1.6**		
III	$x_{up}=5.6$			
<i>Phellodendron amurense</i>				
I	$x_{down}=4.7$	1.8**	1.2**	0.3504
II	$x_{middle}=3.5$	0.6*		
III	$x_{up}=2.9$			

As shown in Table 4, the difference of DBH growth of *Fraxinus mandshurica* between the middle- and up-slope and between the middle- and down-slope are very significant. Middle slope is best site for diameter growth of *Fraxinus mandshurica*. *Juglans mandshurica* grew best at middle slope. There exists very significant difference between middle, down and up slope, but the difference (0.3) is not significant between the middle and down slope. The growth of *Phellodendron amurense* in diameter is best at down slope, with very significant difference between down slope and up slope, but the difference between up- and mid-slope is not significant.

The same method was used to analyze the difference in height growth at up-, middle-, and down-slope for three species (Table 5)

**Table 5. Multiple comparison analysis of every factor for height growth**

Level	Average height	$x_i - x_{up}$	$x_i - x_{down}$	LSD (0.05)
<i>Fraxinus mandshurica</i>				
I	$x_{middle}=4.8$	1.4**	0.1	0.6572
II	$x_{down}=4.7$	1.39**		
III	$x_{up}=3.4$			
<i>Juglans mandshurica</i>				
I	$x_{middle}=7.6$	1.2**	0.4*	0.5068
II	$x_{down}=7.2$	0.8*		
III	$x_{up}=6.4$			
<i>Phellodendron amurense</i>				
I	$x_{down}=4.9$	1.7**	0.2	0.3504
II	$x_{middle}=4.7$	1.5**		
III	$x_{up}=3.2$			

As shown in Table 5, *Fraxinus mandshurica* grew

best in height at middle slope. The difference (1.4 m) with up slope is very significant, but the difference is not significant between middle and down slope. Middle slope is also the best site for height growth of *Juglans mandshurica*. The difference (0.4) between middle and down slope is significant. *Phellodendron amurense* grew best in height at down slope, and there exist not significant difference between down and middle slope (0.2).

As shown in Table 4 and 5, the growth trend of diameter and height of the three species are same, or DBH growth and height growth are simultaneous in juvenile period.

The standard trees were selected to make stem analysis in every plot with different species. Height growth was measured according to twigs. Results were shown in Fig. 1~6. The total trend is that both DBH and height of three species grew rapidly in juvenile period (11 years), and the growth rate is linear correlation with age. *Juglans mandshurica* grew rapidly in height, with little difference, since 1991. Diameter and height of *Fraxinus mandshurica* grew slowly before 1993 and have little difference in growth at different slope position. After 1993, *F. mandshurica* grew rapidly and the difference at different slope position occurred. The trees' growth at middle and down slope is superior to that at up slope. *Phellodendron amurense* grew best at down slope and worst at up slope, with significant difference at different slope. This result is not agreement with the conclusions reached by Li Junqing (1991): "up slope suit to *Phellodendron amurense*, down slope suit to *Juglans mandshurica*", but same as that reached by Zhou Xiaofeng (1980): *Fraxinus mandshurica* suit to sides and gullies of the mid-slope.<sup>[4]</sup>

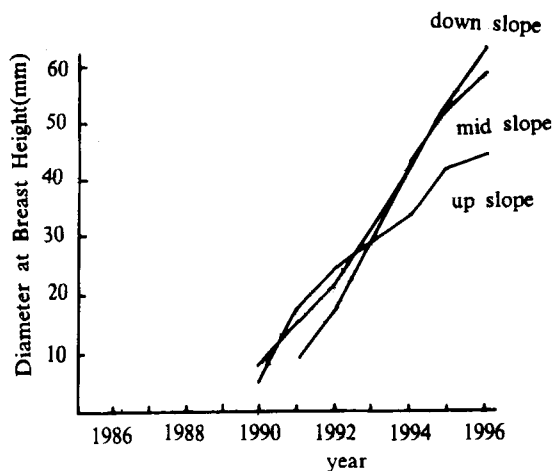


Fig. 1. DBH annual growth of *Juglans mandshurica*

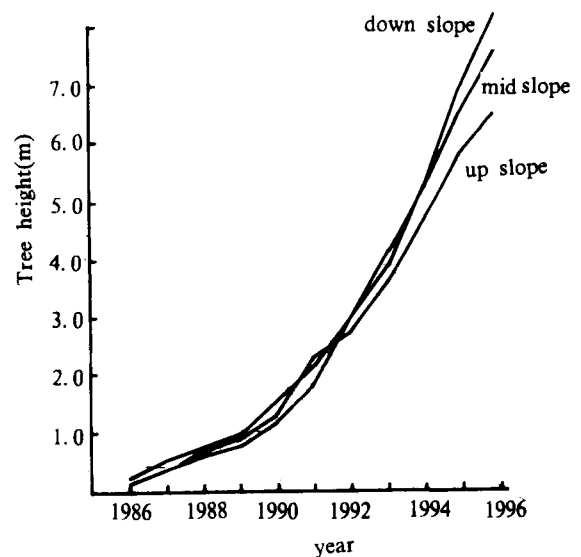


Fig. 2. Height annual growth of *Juglans mandshurica*

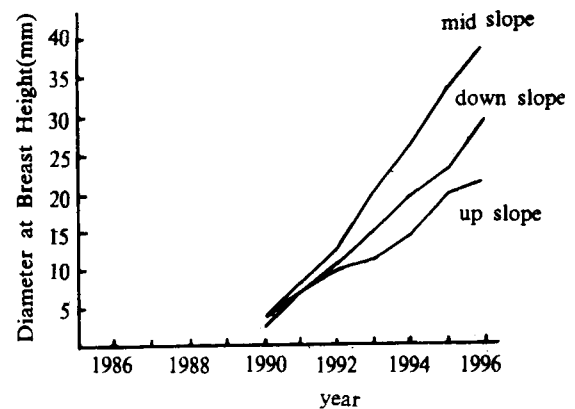


Fig. 3. DBH annual growth of *Fraxinus mandshurica*

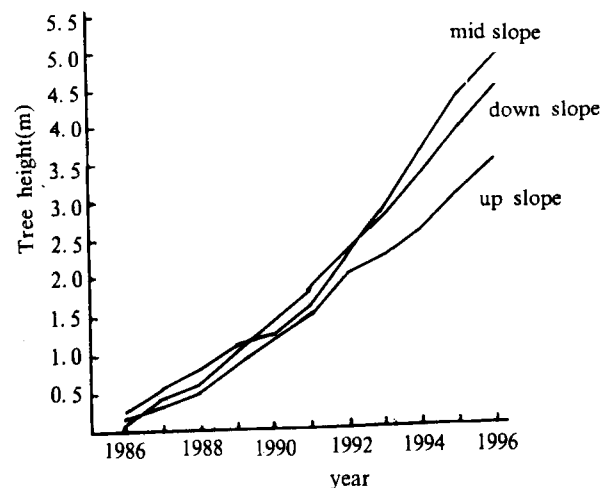


Fig. 4. Height annual growth of *Fraxinus mandshurica*

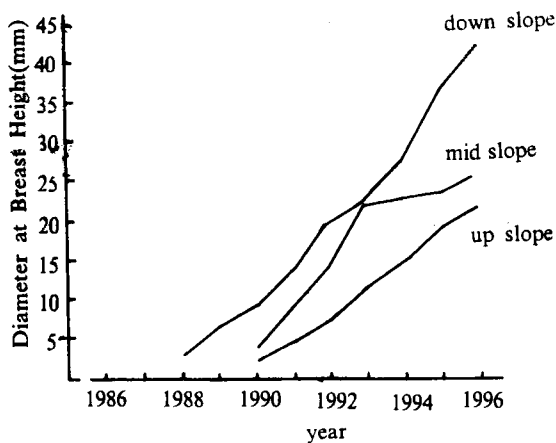


Fig. 5. DBH annual growth of *Phellodendron amurense*

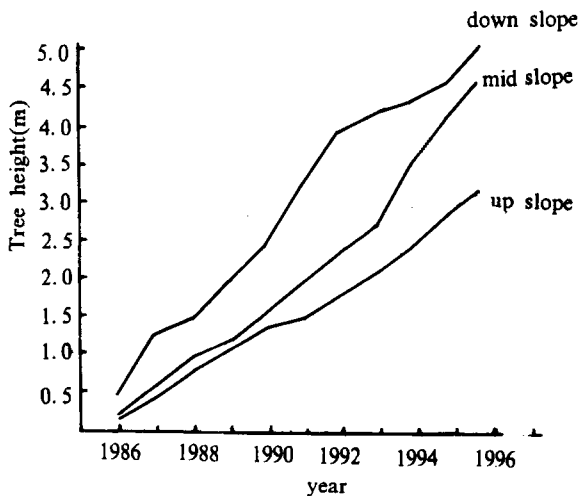


Fig. 6. Height annual growth of *Phellodendron amurense*

The disposition of belt-mixed forest from one side to another is *Larix dahurica*(3 lines), *Juglans mandshurica* (6 lines), *Larix dahurica*(3 lines). DBH and

height growth of *Juglans mandshurica* adjacent to *Larix dahurica* are larger than average growth of *Juglans mandshurica* by analysis of variance and the difference is very significant( $F$  value: 4.20--up, 4.23 --middle, 4.35--down). It shows that growth of *Larix dahurica* and *Juglans mandshurica* have positive edge effect (same as Chen Zhiguo, 1991)<sup>[5]</sup>.

## Conclusions

Slope affected the DBH and height growth of *Fraxinus mandshurica*, *Juglans mandshurica* and *Phellodendron amurense*. Middle or down slope suit to *Juglans mandshurica*, *Fraxinus mandshurica* grows well at middle slope, and *Phellodendron amurense* grows well at down slope.

The three species grew slowly at all slope position before 7~8 years(planting seedlings) and grew rapidly after 8~9 years(tree crown closed).

There are positive edge effect in belt-mixed forest of *Juglans mandshurica* and *Larix dahurica*.

The order of absolute growth rate of DBH and height is: *Juglans mandshurica*( DBH 7.5 cm and Height 7.6 m); *Fraxinus mandshurica*(DBH 4.7 cm, height 4.8 m) *Phellodendron amurense*(DBH 3.5 cm, height is 4.7m).

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